Novel Optical Organic Aerogel Composite Filters

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Purpose

To develop wavelength specific light filters using crystalline colloidal arrays (CCA).

Background

Colloids can be produced with the properties such that the surface charges residing on the colloidal particles cause the particles to form a regular array within the solvent. Such an array is called a colloidal crystal. Since the size of colloidal particles can be made on the order of the wavelength of visible light, it is possible to design arrays to act as a diffraction filter for a specific wavelength of light. What wavelengths are filtered depends on the wavelength of the light and the angle at which it hits the array. CCA's with the potential for this application have been made of polystyrene spheres in a polyacrylamide hydrogel and silica spheres in polymerized acrylic/ methacrylic ester films.

One significant limitation on the production of these materials is that reproducibility of material appears poor. To form a useful material, the CCA structure must be preserved in some manner. This may be done by free radical photopolymerization of a material in the solvent phase to some significant level of conversion. While the resultant polymer network locks the colloidal array into immobile positions, the process inevitably distorts the array.

Polymerization results in convection due to temperature and solutal gradients associated with the reaction. These gradients are unavoidable due to the attenuation of the initiating light source by the fluid with increasing penetration depth. In addition, the surface charges which control the lattice spacing are easily changed by temperature changes. Furthermore, the surface charges may be weak in comparison to volumetric forces such as convection. Finally, the final products have a different volume, typically smaller, than the initial reactants.

A particularly surprising finding is that this shrinkage in lattice spacing is almost totally in a single dimension for reactions carried out between glass slides used in forming silicapolyacrylic films. Apparently, the array is bound in some manner to the glass, and the resulting array structure changes from face-centered cubic to rhombohedral. In sum, distortion of the lattice can be expected if a chemical reaction is used to immobilize the array.

The goal of this year's research was to study the effects of convection on the distortion of a silica/ acrylic array.

Approach

The Schimdt, Prandtl, thermal Rayleigh, and solutal Rayleigh numbers of the reaction solution were estimated from published thermophysical properties. The numbers obtained were 580, 7.2, –83,000, and 230 respectively. Note that the negative thermal Rayleigh number indicates a denser product than the reactant. Based on these numbers, solutal effects are expected to dominate convection. Since the reactant density is less dense than the product density, this implies that the

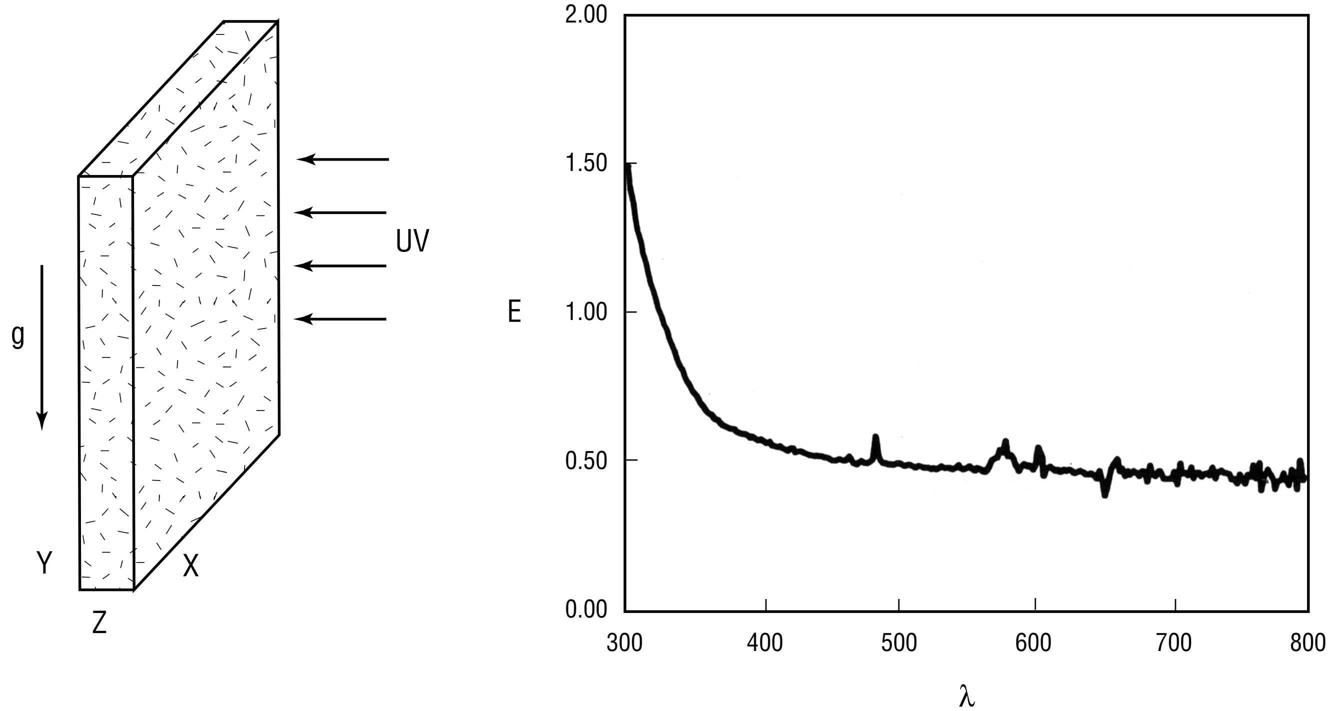

Figure 43.—Photoinitiated from the side with cell in a vertical orientation.

orientation in which convection would be minimized during processing would be for the photon source to illuminate the reaction cell from below.

The 20×70×0.264-mm photocell in which polymerizations of the silica/acrylate array were carried out was positioned in two different orientations. When photoinitiated from the side with the cell in a vertical orientation (fig. 43) no extinction was observed in the polymerized material for any wavelength. This indicated that the array had been destroyed, at least in practical terms, by the convection occurring during reaction. When photoinitiated from above with the cell in a horizontal orientation (fig. 44) an extinction peak was clearly observed near 500 nm as can be seen in the figures. The results indicate that while convection can easily effect or destroy the array, very simple steps can be taken to reduce its effects. It is also important to note that the latter orientation is not the most stable. Due to the dominance of solutal convection, exposure from below would be the orientation least prone to convection.

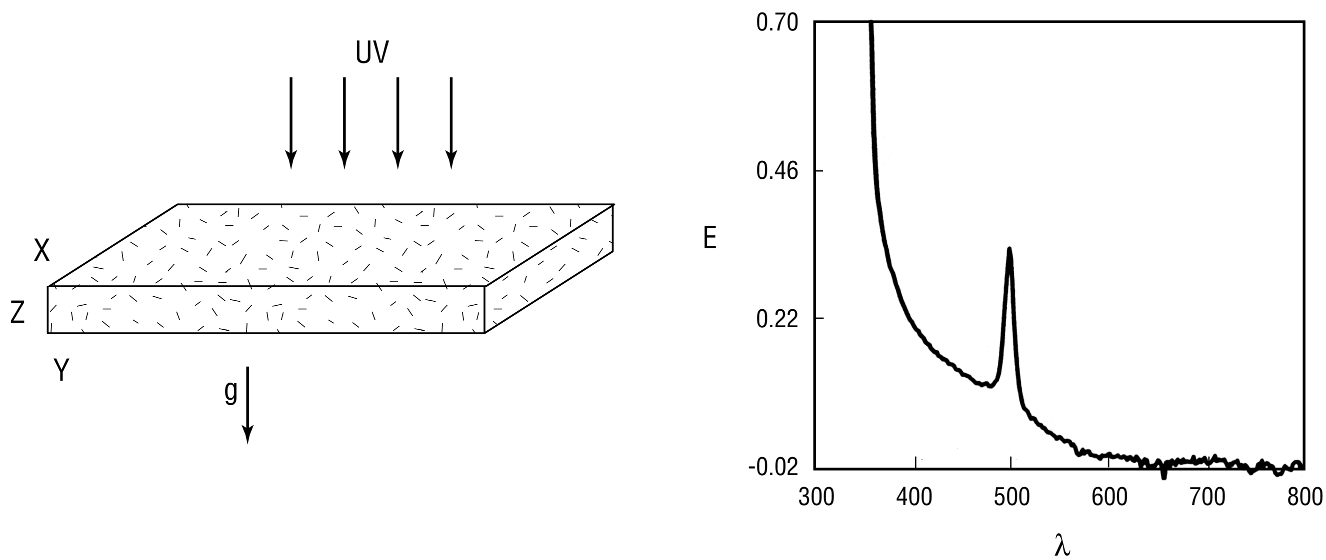

Figure44.—Photoinitiated from above with the cell in a horizontal orientation.

Planned Future Work

Possible work is to convert a polymerized CCA array to an aerogel via removing the solvent using supercritical CO_2 extraction. Such aerogels would be lightweight and impervious to partial drying out effects which can happen when a solvent remains in the polymer network. Also, microgravity and magnetic damping experiments are possible to determine the relative effects, on lattice distortion, of convection and temperature-dependent changes in charges on the particles. However, no further work is planned at this time due to a shortage of manpower.

Publications

Sunkara, H.B.; Penn, B.P.; Frazier, D.O.; Ramachandran, N.: “Lattice Dynamics of Colloidal Crystals During Phopolymerization of Acrylic Monomer Matrix,” submitted to *J. Materials Science*, March 1997.

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Status of Investigation

Terminated